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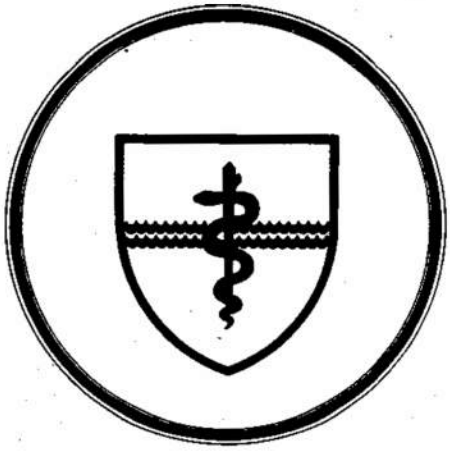


REPORT NUMBER 955

SURVEYS OF LIGHTING AND WORKING CONDITIONS IN SUBMARINE SONAR SHACKS

by

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Naval Medical Research and Development Command
Research Work Unit M0100-PN-001-1014

Released by:

R. A. Margulies, CAPT, MC, USN
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9 June 1981

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## SUMMARY PAGE

The Problem:

To determine the physical, working conditions within sonar shacks of operating submarines that might affect performance.

The Results:

Conditions were so diverse, even for the same sonar system, that it appears they could not all be optimally effective.

Applications:

The variables identified in this study will be employed in an experimental assessment of their effects on performance and comfort in order to recommend optimum conditions.

## ADMINISTRATIVE INFORMATION

This research was conducted as part of the Naval Medical Research and Development Command Work Unit M0100-PN.001-1014 - "Optimum conditions for watch in sonar shacks." It was submitted for review on 2 June 1981, approved for publication on 9 June 1981, and designated as NSMRL Rep. No. 955.

PUBLISHED BY THE NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

## ABSTRACT

A survey of the physical, working conditions of twelve operating submarines was completed. The purpose was to determine the range of conditions normally encountered in sonar shacks. These conditions will next be assessed for their effects on performance and comfort so that optimum conditions can be specified. The results showed a great diversity of illumination, both in color and quantity, on the various sonar systems. Effective levels of illumination are generally considerably higher under blue light than under red. While the duty-cycle of six hours on and 12 hours off watch was standard, rotation periods during watch varied. Several conditions within the sonar shack could be changed to improve working conditions.

Technologically, the capabilities of the newer sonar systems are most impressive, but even a casual inspection of the sonar shacks suggests that the physical conditions under which the sonar technicians work are much less impressive. Many improvements are desirable and possible. Complaints are common concerning both eye fatigue and the general decline in alertness and efficiency over time on watch. This study is part of a larger research effort whose goal is to improve the working conditions, reduce the complaints and visual problems, and thereby improve the effectiveness of the sonar operator.

A large number of physical variables could be manipulated in an effort to achieve this goal; these include lighting, brightness, contrast, glare, time on watch, physical comfort, noise, air quality and many others. This is a report on the first phase of the research, a survey of existing operating conditions in an attempt to identify the important variables to be manipulated.

## The Ships

Twelve operating submarines were surveyed. Three of these were FBM's of the 616 and 640 classes. The other nine were fast attack ships of many different types, ranging from one of the oldest in the operating fleet to the newest 688 class submarines. The sonar shacks were likewise diverse, both in size, equipment, and lighting.

## Items Surveyed

One of the major items in the survey was the quality and quantity of the lighting conditions. Quality refers to the color of the ambient illumination and the possibility of glare. Quantity of light included the amount of illumination falling on various work areas and the luminance of various self-lighted displays. The use of color coding and the type of lighting contrast on displays was also assessed.

The size of smallest detail which had to be perceived and the distance of displays from the operator were measured; also, operators were questioned concerning the length of watches, the amount of rotation completed within a watch, and smoking habits.

In addition comments were solicited during the survey concerning aspects of the sonar shack and of the working conditions that the sonar technicians thought were particularly helpful or disturbing.

# RESULTS

## Lighting Conditions

Information was solicited on all submarines about the lighting under normal operating conditions. The results of this survey are given in Table I. Of the twelve ships surveyed, four had installed the experimental, overhead blue lighting in all fixtures; three of these reported using it for normal operating conditions, while the fourth turned off all overheads except for one blue fixture. Four reported that the normal operating condition was red illumination; two others used red supplemented by white,stray light from either reading lamps or the BQQ3. The remaining two employed "rig for black";

Table I. Summary of lighting during operating conditions

| Type of Submarine | Color of Lighting | | | Illumination on major sonar system Range in footcandles | Illumination of working shelf Range in footcandles |
|---|---|---|---|---|---|
| | Red | Blue | Black | | |
| Older Attack | | | | | |
| N= 5 | 3 | 1 | 1 | <.01 to .25 | <.01 to .62 |
| Newer Attack | | | | | |
| N= 4 | 2 | 2 | 0 | .02 to .28 | .02 to .37 |
| Missile | | | | | |
| N= 3 | 1 | 1 | 1 | <.01 to .05 | .034 to .06 |

that is, overhead fixtures were turned off and the only illumination was supplied by stray light (which could be red or white) from instruments.

Illumination on the major sonar system in each type of submarine varied greatly, from less than .01 footcandles (fc) (the lowest value measurable with the light meter) to .28 fc. Similarly illumination on working areas, generally the small shelf in front of a major system, varied from less than .01 to .62 fc.

Similar large ranges were found even when comparison was restricted to the same sonar systems. All of the newer attack submarines listed in Table I have the BQQ5, yet the quantity of illumination falling on the CRT's varied from .02 fc of red light to .28 fc of blue.

Measures of the illuminated chart on the BQQ3, from seven different submarines are given in Table II. This system has its own built-in light sources and commonly has both bright white and either red or dim white alternatives. Values are generally higher on the BQQ3 than on the major systems of Table I; this reflects the need for discriminating fine visual detail on this classification system. Also this system provides much of the stray light provided for general room illumination for those ships that rig for black. Values, under normal operating conditions, vary from 1.5 foot-Lamberts (fL) of red to 50.5 fL of white, another example of the great diversity of lighting for the same sonar system.

This range of light levels is even greater than indicated by the measured quantities. All the measurements were made in normal, photopic or daylight levels of illumination. However, many of the lower values (.01 to .1 fc) are not photopic but are actually mesopic* levels of illumination. Photopic units are not appropriate under these conditions since the spectral sensitivity of the eye has shifted toward its nighttime or scotopic state.[1] The consequences of this are that shorter wavelengths (blue and blue-green) are brighter or give more light than the measurements indicate while long wavelengths give much less. While there are no light meters available with which to make mesopic light measures, there are techniques by which the magnitude of the effect can be calculated.[2,3]

The amount of illumination falling on the BQR 21 on two different submarines will illustrate the magnitude of the effect. As measured with the photopic light meter, one ship had .04 fc of red illumination while the other had .035 fc of blue. The two measured quantities are very similar (slightly more red) but fall within the mesopic region where our standard light meters misrepresent the real sensitivity of the eye. Calculations of the actual effectiveness of the red and blue lights at this level yield .099 fc of blue and .029 fc of red; that is, there is 3.4 times as much blue light as red falling on the two sonar systems.

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* Mesopic refers to the middle range of light levels between day vision and night vision.

Table II. Color and luminance on BQQ3 on seven different submarines under normal operating conditions

| Ship | Color | Luminance (fL) |
|---|---|---|
| 1 | white | 13.3 |
| 2 | blue | 5.4 |
| 3 | white | 50.5 daytime |
| | red | 2.5 nighttime |
| 4 | white | 32.8 |
| 5 | white | 4.3 |
| 6 | red | 1.5 |
| 7 | white | 2.6 |

## Working Conditions

Conditions of watch. All of the ships surveyed reported their normal duty-cycle to be six hours on, 12 hours off. However, there were several reports of longer watches, due to shortages of sonar technicians: two ships had frequent cycles of six hours on and six hours off, while a third had a shortage of supervisors which necessitated an eight- to 12-hour duty for them.

Changes of duties within a watch period varied from rotation every half hour to every two hours, with the majority reporting all three sonar technicians rotated every hour.

Details of visual environment. The size and shape of the sonar shacks and the location of the sonar systems and the lighting fixtures within them varied from ship to ship. Consequently there were reports of glare sources in the field from half of the ships and of none from the other half.

Most men reported very little use of color coding within the sonar shack, maintenance and repair manuals being about the only example. Additional white lights are obviously necessary for this use, both for the extra light needed and to see colors.

All of the CRT's have controls by which contrast can be adjusted but generally no indication is provided as to the level at which it is set. Most sonar technicians reported setting contrast to look good on some subjective basis, such as "as dark as possible" or "whatever looks good." The reports from eight out of the 12 ships were that different operators set it differently.

The smallest visual details to be discriminated were generally 5 minutes of visual angle in size or larger; this should not provide a problem for anyone who is adequately corrected for the close observing distance.

The distance from operators to their consoles varied from 18 inches to 31 inches with a mean of 24 inches and a standard deviation of 3.7 inches. The chairs were frequently fixed to the deck so that change was not possible. There were serious complaints from the men with the closest viewing distance.

## Air Quality

On eight of the submarines, at least one half, commonly more, of the men smoke. There were complaints from sonar crews of two-thirds of the ships about smoking and most reported that, at one time or another, they had tried to schedule non-smokers together. However, experience and personality factors over-rode smoking preferences in selection for sections and there was no workable system for dealing with smoking on any of the ships at the time of the interview.

There are no air quality monitors in the sonar shack and complaints of inadequate or uneven ventilation also occurred, as described in the next section.

## Comments and Complaints

During the surveys of the sonar shacks, an effort was made to solicit complaints so that we could obtain information on the conditions that

were most objectionable to the men. Four topics accounted for almost all of the complaints and were mentioned by men on at least four ships; these were the ventilation, the seats, the size of the shack, and red lighting. Inadequate ventilation was by far the most common complaint, being mentioned by men on nine of the submarines. Some sonar shacks were too hot (generally 85°F), some too cold and on three ships, it was described as uneven: that is, it was too cold close to the ventilators and too hot in the corners.

The second most common complaint, mentioned by five crews, concerned the seats in the sonar shacks. These were described as uncomfortable, hard, the wrong shape, located at the wrong distance, and as "junk" (always broken). An additional complaint was the lack of a chair or stool for the supervisor on some submarines.

The size of the sonar shack (too small, cramped, crowded) was the source of a number of complaints as was red lighting (too dark, uncomfortable, causes headaches).

Excessive noise and uncomfortable head sets were mentioned infrequently. Interestingly, some crews had alleviated the noise problem themselves by installing a carpet.

## DISCUSSION

The results of this survey of physical conditions in submarine sonar shacks have several practical applications. Of major importance is that the information on existing conditions has been gathered. Thus variables have been identified which will be used in an experimental asessment of their effects on performance and on feelings of comfort and fatigue. Moreover the range of conditions is so large that it seems obvious that not all can be optimum. For example, illumination on the same console which varies in quantity, by factors of ten or one hundred, and in color must have an effect on the visibility of contacts on the console. The question of which condition yields best performance will be addressed in the second phase of this research project.

A second important application is that the results suggest a number of areas in which improvements could be made to make the work of the sonar technician more agreeable. While it is true that, in any job, there is probably always something about which to complain, the fact that the same complaints are common to many submarines suggests they have real substance. Some of the areas, such as inadequacy of ventilation, may be difficult to improve, except in new construction. Others, however, should be relatively easy: the installation of carpet, if noise is a problem; the provision for good, local lighting with, for example, gooseneck lamps; and improved design of chairs or seats. The latter is an area in which considerable information is available; human engineers have developed optimum designs for comfortable seats.[4] Trial of these in sonar shacks could be instigated.

Finally, the complaints against red lighting and the popularity of blue raise questions which need to be addressed. Red lighting within submarines was, of course, originally installed to promote the dark

adaptation of lookouts when submarines had to snorkel frequently. With the advent of nuclear submarines, it was maintained primarily for periscope operators.[5] There is however little need for it in modern submarines,[6] particularly in the sonar shack, and the requirement for dual lighting systems, red and white, has been eliminated from the newest classes of submarines. Thus when the suggested change to blue occurred,[7] it was apparently greeted with enthusiasm in the fleet and is now installed in a number of submarines.

There are at least three reasons for the popularity of blue over red. First is the well-known, psychological effect of improved morale which stems from any change that the participants perceive as being done for their benefit.[8] Second is the fact from physiological optics that long wavelengths (red light) focus farther behind the retina than light of shorter wavelengths and thus require more accommodation to see clearly at the same distance. This can be particularly uncomfortable for hyperopes (far-sighted individuals) or for older men who are utilizing most of their accommodative power under close viewing conditions and do not have the reserve for the long wavelengths. Finally blue lights, as installed in the sonar shacks, provide much more total light than do the red. Even if they measured the same with a photopic light meter (which they did not, blue was generally brighter), blue is much more effective in providing light at the low levels found in the sonar shack than is red. Thus there are real reasons for the men's preference of blue over red.

Whether blue would also be preferred to white (which allows color coding) is another question to be answered in the next phase of the research.

REFERENCES


1 Kinney, J.A.S. Degree of applicability and consequences of inappropriate uses of units of light. Appl. Optics 6, 1473-1477, 1967.

2 Bureau Central de la CIE, Light as a true visual quantity: principles of measurement. Publication CIE No. 41 (TC-1.4) 1978.

3 Palmer, D.A. Standard observer for large-field photometry at any level. J. Opt. Soc. Am. 58, 1296-1299, 1968.

4 Mandal, A. C. The seated man (Homo Sedens) The seated work position. Theory and practice. Appl. Ergonomics 12, 19-26, 1981.

5 Kinney, J. A. S., S. M. Luria and D. O. Weitzman. Analysis of a variety of visual problems encountered during naval operations at night. NSMRL Rep. No. 545, 1968.

6 NSMRL ltr NSMRL-01, 3900, Ser 1664, 18 Nov 1970 Subj: recommendation regarding dual lighting systems new SSN construction.

7 COMSUBLANT SPDLTR FF4-12: N223 9330 Ser 2930 of 28 May 1980.

8 Brown, J. M., F. K. Berrien and D. L. Russell. Chapt 10 in Applied Psychology, New York: Macmillan Co. 1966, pp 341-378.

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| 3. RECIPIENT'S CATALOG NUMBER | |
| 4. TITLE *(and Subtitle)*: SURVEYS OF LIGHTING AND WORKING CONDITIONS IN SUBMARINE SONAR SHACKS | 5. TYPE OF REPORT & PERIOD COVERED: Interim report |
| | 6. PERFORMING ORG. REPORT NUMBER: NSMRL Report No. 955 |
| 7. AUTHOR(s): J. A. S. Kinney, S. M. Luria, D. F. Neri, S. W. Kindness, and C. L. Schlichting | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Submarine Medical Research Laboratory, Box 900, Naval Submarine Base, Groton, Connecticut 06349 | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 65856N M0100PN001-1014 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Submarine Medical Research Laboratory, Box 900, Naval Submarine Base, Groton, Connecticut 06349 | 12. REPORT DATE: 9 June 1981 |
| | 13. NUMBER OF PAGES: 7 |
| 14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*: Naval Medical Research and Development Command, National Naval Medical Center, Bethesda, Maryland 20014 | 15. SECURITY CLASS. *(of this report)*: Unclassified |
| | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

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18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Submarine sonar shacks; lighting; visual fatigue

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

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